Probability description of final state distribution in independent fragmentation model*

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The paper presents a probability account of the density distribution for final states in a class of independent fragmentation models. The formalism leads to a simple but exact expression for the single particle distribution of the final states. As an example, we discuss a particular model used in high-energy parton-parton and e^+e^- scatterings — the independent jet fragmentation model. The universality and simplicity of the probability description allow us to apply our formalism to various physical processes of fragmentation nature.

Fragmentation processes, cascading phenomena, and their corresponding inverses — connectivity and clustering problems — are of fundamental interest in many different fields. In physics, examples are the jet fragmentation process of quarks and the bremsstrahlung process of charged particles. As an example, the process of jet fragmentation plays an important role in high-energy e^+e^- scatterings and high-energy parton-parton scatterings in pp, $p\overline{p}$, pA, and AA collisions. However, there is no first-principle theory that can be used to derive the final state distribution for the jet fragmentation process. The reason for this is that the fragmentation of quarks into hadrons is a non-perturbative phenomenon and is not calculable within the framework of the strong interaction theory — QCD. Therefore, one has to develop phenomenological models to describe the density distribution for final states. The scaling behavior involved in the jet fragmentation is certainly a useful feature that simplifies the problem. In the last two decades various models for jet fragmentation have been proposed.

Models studied so far can be classified into three categories: independent fragmentation, clustering, and strings. The independent fragmentation model was first proposed by Field and Feynman. This simple model has served as a building block in jet fragmentation studies. Recently, more sophisticated models such as the string model have been studied in the literature for e^+e^- scattering. Even though the independent fragmentation model is no longer widely used in the current version of Monte-Carlo generators for jet fragmentation in e^+e^- scattering, it is still used for parton-parton scattering in pp, $p\overline{p}$, pA, and AA collisions. Furthermore, the independent jet fragmentation model has its own merits because of its simplicity and universality.

We propose a probability description of the density distribution for final states in a class of independent fragmentation models. The focus of our study has been on the development of a simple but *complete* probability description for the independent fragmentation process. The approach we developed has a sound mathematical basis and is an extension of the early work by Field and Feynman. It should be pointed out that our method works not only for a particular model — jet fragmentation, but also for other physical processes of a fragmentation nature, such as bremsstrahlung.

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